ICE PRESSURE MEASUREMENT UNDER FLOWING CONDITIONS ON HARBIN REACH OF SONGHUA RIVER

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ABSTRACT
In April 1999, the measurement and investigation work at the position of No. 3 pier of Songhua River highway bridge in Harbin was carried out. Built in the 80’s, this bridge suffers severely from ice floods. Before the ice cover melted, five ice pressure transducers were firmly installed at different locations at the head of No. 3 pier on the upstream side. During ice drift, using relative apparatus, measurements of ice pressure were performed. Through these measurements of ice pressure, two typical samples and two complete curves of ice pressure have been recorded by the measurement apparatus.

Based on the records provided by the hydrologic observation branch during the period of this measurement, the water level of the drifting ice was classified as moderate. The magnitude of the drifting ice was not the largest observed. In fact, the drifting ice sheet that impacted on No. 3 pier was not the largest one either.

INTRODUCTION
The Songhua River of the north-east region of China, located at 44°–46° N, is in a cold region and is one of the rivers with the most serious drifting ice problems. With an increase in air temperature, the river ice cover begins to form ice floes and ice sheets, which can impact upon bridge piers and hydraulic buildings, so that they cause diverse damage of varying amounts.

In recent years, in order to study the ice action on bridge piers, Chinese researchers performed various dynamic tests on drifting ice. Cai et al. (1997) adopted an indirect procedure and measured the dynamic response under the river ice load in Jiamusi reach of the Songhua River.

At the beginning of April 1999, in order to carry out further research on the interaction between moving ice and bridge piers, the dynamic force on piers under natural drifting ice was measured in the Harbin reach of Songhua River, and the values and curves of ice pressure were recorded. This is the first river ice pressure test performed under natural

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ICE PRESSURE MEASUREMENT ON A BRIDGE PIER

Instrument and equipment for measurement

A schematic diagram of the measurement of the river ice pressure is shown in Fig. 1.

Figure 1: Schematic diagram of ice pressure measurement

Ice pressure transducer
They have been made by IEM State Seismological Bureau and they are pressure-resistant models. The form of the transducer is a rectangular box about 0.6 m × 0.2 m × 0.06 m, with a weight of about 343 N. A length of 0.6 m is to accommodate a change in ice water level. The transducer employs semiconductor strain gages with high sensitivity as pressure/voltage conversion elements.

Five pressure transducers were used for this measurement and were firmly installed at different locations at the head of No. 3 pier on the Songhua River highway bridge in Harbin.

Magnetic-tape recorder R-81 model
This was made by the Japan TEAC company and complete curves of ice pressure were recorded.

Analyzer HP3562A
This was made by US HP company. The dynamic signal analyzer is used to analyze the ice pressure signal. The amplitude, frequency, phase and spectrum of various dynamic signals can be analyzed and controlled.

Drawing instrument
This was made in the US and is used to draft the curves produced by the analyzer.

Direct supply
The transducers were provided with a direct supply producing a voltage output of +4.5 V as the bridge voltage.

Installation of the ice pressure transducers
No. 3 pier was chosen as the measurement object, because the pier is just located in the center of the main river and is impacted by ice floes and ice sheets with greater probability.
Five transducers were firmly fixed on the head facade or on the front side of the pier by the expansion bolts. The installation of the transducers had to be finished before April.

Figure 2: The layout of measuring points of pressure transducers for No. 3 pier of the highway bridge over Songhua River

To ensure the ice pressure values and curves could be obtained and precisely measured, the range of the elevation at which the transducers were mounted (Fig. 2) was based on the predictions of the drifting ice water level, which was provided by the hydrologic branch.

**Measurement result and its appraisal**

The initial movement of the ice sheet began on 12 April 1999. At that time our measurement had already been prepared. On the morning of April 15th congested drifting ice began to appear again. The movement of the ice floes or sheets at 2:00 pm had reached the high tide. A large number of ice floes and sheets, of which the biggest was about an area of 80 m x 100 m, were pushed along with the current. In the meantime, all four transducers, other than No. 2, were impacted by the ice floes and sheets with collisions of different degrees. The complete ice pressure values and curves were obtained, as shown in Table 1 and Figs. 3–4 respectively.

**Table 1 Measurement results of ice pressure on No. 3 pier**

<table>
<thead>
<tr>
<th>Transducer No.</th>
<th>Time (h/m)</th>
<th>Water level of drifting ice (m)</th>
<th>Ice pressure value (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14:54</td>
<td>114.60</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>14:54</td>
<td>114.80</td>
<td>0.32</td>
</tr>
<tr>
<td>4</td>
<td>15:53</td>
<td>114.60</td>
<td>0.21</td>
</tr>
<tr>
<td>5</td>
<td>15:53</td>
<td>114.90</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Figure 3: Ice pressure curves measured by No. 1 and No. 3 transducers on No. 3 pier at 14:54, Apr. 15, 1999

Figure 4: Ice pressure curves measured by No. 4 and No. 5 transducers on No. 3 pier located in north side of main stream at 15:53 Apr. 15, 1999

In the drifting ice process, the area of the ice floe and sheet that dashed No. 3 pier was not the largest present. So the ice pressure values measured were certainly not the largest possible.

Figure 5: Tremor measurements of Songhua River Highway Bridge at 14:54 Apr. 15, 1999
IMPULSE MEASUREMENT ON THE UPPER DECK OF THE BRIDGE

On the upper deck of No. 3 pier two 701-model impulse transducers, which were made in China and which were mounted in advance, were used to measure the vibration behavior of the bridge. The impulses were produced at the same time as drifting ice acted on the pier. Impulse transducer No. 1, which was mounted parallel to the axis of the bridge, was used to measure the longitudinal vibration displacement on the deck of the bridge, while impulse transducer No. 2 was mounted perpendicular to the axis of the bridge to measure lateral dynamic displacement.

On 15 April, 1999, in the afternoon at 2:54 pm, while the ice pressure on No. 3 pier was being measured simultaneously, impulse frequency and lateral/longitudinal impulse response power spectrum curves on the deck of the bridge at the vertex of the pier were obtained (see Table 2 and Fig. 5).

Table 2: Impulse frequency of bridge surface

<table>
<thead>
<tr>
<th>Impulses</th>
<th>time</th>
<th>Direction to bridge axis</th>
<th>Impulse frequency range (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2:54 pm</td>
<td>parallel</td>
<td>1.5–4.2</td>
</tr>
<tr>
<td>2</td>
<td>2:54 pm</td>
<td>perpendicular</td>
<td>12.5–17.5</td>
</tr>
</tbody>
</table>

Due to the fact that traffic was not held up, the precision of measurement was influenced to a large extent. The result described below can be regarded as a study of the bridge vibration mechanism.

THE PIER IMPACTED BY DRIFTING ICE WITH SITE RANGE ESTIMATION

In order to understand the interaction characteristics between the ice and the pier, we made random daytime observations at the site from April 12 to 16.

Based on the prediction supplied by the hydrologic observation branch in advance, in the 1999 spring season, both the height of the water level and the severity of the extent of the drifting ice were both moderate.

When we arrived at the site of the bridge on the morning of April 16 at 8:00 am, we were surprised by a huge ice-sheet that blocked the foot of No. 3 pier. The length of the ice sheet was more than 100 meters, and it was 70 m wide and 0.4 m thick. It was really a pity that we could not measure the ice pressure flung against No. 3 pier. Then, about 11:00 am a large sheet, which was 60 m in length and 50 m wide, collided with No. 2 pier. At that time we heard a peal of thunder at the foot of No. 2 pier and saw a slush mound in the forward position of the ice sheet. In the meanwhile, the ice sheet backed up about 1.0 m, obviously as a result of the rebound with the pier. From that afternoon, the ice floes and sheets evidently started to decrease.

At the site of the bridge, we clearly felt the vibration of the bridge brought about by the piers, which were dashed by the large ice sheet. Owing to the high strength and large stiffness of the structures of the bridge piers and its deck, the deformation/displacement produced was not worth mentioning at present. The bridge designs in China consider only the internal forces produced by the ice pressure, but do not consider the influence of deformations and vibration displacements on the safety of bridges.
CONCLUSIONS
This site test was conducted under conditions of natural drifting ice. The complete sequence and results of drifting ice action on the bridge piers in the Harbin reach of Songhua River were directly measured and recorded. The desired outcomes have been achieved. As mentioned above we can draw the following conclusions.

1. For ice pressure measurement on No.3 bridge pier, the pressure value and pressure-history curves for drifting ice that impinges against the bridge pier were obtained and the whole course of interaction between the ice and the pier was actually recorded.

2. The impulse measurement carried out on the deck of the bridge indicates that the deformation and displacement of the bridge are all very limited. Since the impulse signal was subject to the influence of the vibration noise of driven vehicles, its error is larger.

3. This test was conducted under moderate, or below moderate, ice conditions. Therefore, the bridge pier suffered from ice action that was not the most severe possible. However the data and information obtained from this measurement test provide a significant foundation for further developing drifting ice action on bridges, and for working out more reasonable calculation formulae for the ice pressure which can provide some references for building more bridges in the future.

REFERENCES